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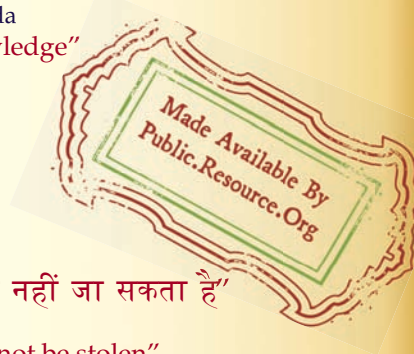
IS 9778 (1981): Guide for evaluation of thermal endurance of varnish bonded glass-fibre covered rectangular copper conductors [ETD 33: Winding Wire]



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IS : 9778 - 1981

(Reaffirmed 2005)

Indian Standard

GUIDE FOR EVALUATION OF THERMAL ENDURANCE OF VARNISH BONDED GLASS FIBRE COVERED RECTANGULAR COPPER CONDUCTORS

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GUIDE FOR EVALUATION OF THERMAL ENDURANCE OF VARNISH BONDED GLASS FIBRE COVERED RECTANGULAR COPPER CONDUCTORS

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(Continued on page 2)

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Indian Standard

GUIDE FOR EVALUATION OF THERMAL ENDURANCE OF VARNISH BONDED GLASS FIBRE COVERED RECTANGULAR COPPER CONDUCTORS

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 27 February 1981, after the draft finalized by the Winding Wires Sectional Committee had been approved by the Electrotechnical Division Council.

0.2 The test method covered in this standard is intended primarily for comparing the thermal endurance of varnish bonded glass fibre lapped or braided rectangular copper conductors in air at atmospheric pressure. In due course similar standard to cover round conductors will be prepared.

0.3 Exposure of some types of varnish bonded glass fibre lapped or braided rectangular conductors to heat in gaseous or liquid environments in the absence of air may give thermal endurance values different from those obtained in air. This fact must be considered when interpreting the results obtained by heating in air in respect to applications where the wire will not be exposed to air in service.

0.4 The method described covers only the evaluation of thermal endurance by changes in electric strength. In due course, other test methods to evaluate the changes in other properties will be formulated.

0.5 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This guide lays down a test procedure for evaluating the useful life of varnish bonded glass fibre lapped or braided rectangular copper conductors of thickness ranging from 0.8 to 5.6 mm and width ranging from 2 to 16 mm.

*Rules for rounding off numerical values (*revised*),

1.2 This standard does not apply to enamelled and glass fibre covered rectangular copper conductors.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions shall apply.

2.1 Wire — The insulated material as received.

2.2 Conductor — The bare metal after removal of the glass covering.

2.3 Increase in Dimensions Due to the Covering — The difference between the thickness over the glass covering and corresponding dimension of the conductor.

3. TEST SPECIMENS

3.1 Preparation of Test Specimens — Samples about 350 mm long of the varnish bonded glass fibre covered conductor shall be bent through 180° on the flat around a mandrel having a diameter 10 times the bare thickness of the conductor. About 10 mm of the insulation is removed from one end of the specimen to facilitate electrical connection.

3.2 Number of Test Specimens — The number of test specimens required is 21 for each exposure temperature.

4. TEMPERATURE EXPOSURE

4.1 In Table 1 the suggested temperature and time of exposure in each cycle are given. A test cycle consists of exposure to high temperature; unless otherwise specified the test shall be carried out within a range of 15° to 35°C and a relative humidity range of 45 to 75 percent. Before the tests are made, the specimens shall be preconditioned under these atmospheric conditions for a time sufficient to allow the specimens to reach stability.

Thermal life values obtained from test specimens subjected to an average of less than 8 or more than 20 cycles at the exposure temperature may not be reliable and should not be used to predict the temperature rating of the insulated conductor. A shorter or longer cycle time than those given in Table 1 may, therefore, be chosen for certain exposure temperature to ensure that the average number of cycles to failure falls within this range.

4.2 It is essential that specimens be aged in an oven that will maintain the average temperature of the specimens within $\pm 2^{\circ}\text{C}$ (temperatures lower than or equal to 180°C) or $\pm 3^{\circ}\text{C}$ (temperatures higher than 180°C) of the desired value. At no time shall the temperature deviate by more than $\pm 5^{\circ}\text{C}$ from the average regardless of the number of specimens

TABLE 1 SUGGESTED TEMPERATURES AND EXPOSURE TIMES IN DAYS PER CYCLE

(Clause 4.1)

EXPOSURE TEMPERATURE °C	ESTIMATED RANGE OF TEMPERATURE INDEX OF INSULATED CONDUCTORS										
	130- 139°C	140- 149°C	150- 159°C	160- 169°C	170- 179°C	180- 189°C	190- 199°C	200- 209°C	210- 219°C	220- 229°C	230- 239°C
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
150	28	—	—	—	—	—	—	—	—	—	—
160	14	28	—	—	—	—	—	—	—	—	—
170	7	14	28	—	—	—	—	—	—	—	—
180	4	7	14	28	—	—	—	—	—	—	—
190	2	4	7	14	28	—	—	—	—	—	—
200	1	2	4	7	14	28	—	—	—	—	—
210	—	1	2	4	7	14	28	—	—	—	—
220	—	—	1	2	4	7	14	28	—	—	—
230	—	—	—	1	2	4	7	14	28	—	—
240	—	—	—	—	1	2	4	7	14	28	—
250	—	—	—	—	—	1	2	4	7	14	28
260	—	—	—	—	—	—	1	2	4	7	14
270	—	—	—	—	—	—	—	1	2	4	7
280	—	—	—	—	—	—	—	—	1	2	4
290	—	—	—	—	—	—	—	—	—	1	2
300	—	—	—	—	—	—	—	—	—	—	1

in the oven. It is also preferable that the change of fresh air in the oven be controlled since there is reason to expect that the thermal degradation may be influenced by the fresh air change. There shall be approximately one complete change of fresh air per hour for each square metre of specimen surface.

5. PROOF VOLTAGE TEST

5.1 The test specimens are removed from the oven and cooled to room temperature. To check the condition of the test specimens and to determine the end point of their useful life, each specimen is subjected to a proof voltage test at a frequency of 50 Hz according to the average thickness of the insulation in accordance with Table 2.

TABLE 2 PROOF VOLTAGE

DIFFERENCE BETWEEN BARE AND INSULATED CONDUCTOR DIMENSIONS ON SMALLER AXIS (THICKNESS), mm		50 Hz PROOF VOLTAGE, V (DURATION 1 MINUTE)
Over	Up to and Including	
(1)	(2)	(3)
0.18	0.23	250
0.23	0.33	350
0.33	0.43	450
0.43	0.53	550
0.53	0.63	650

6. APPLICATION OF THE VOLTAGE

6.1 Each U-shaped specimen shall be placed inside a metal container which shall be filled as shown in Fig. 1 with nickel shots, nickel plated shots or stainless steel ball bearings not more than 2.0 mm in diameter, and maintained in a clean condition by washing it, for example, in thichloro-ethylene.

6.2 To detect failure, the over current device shall operate when a current of 5 mA or more flows through the test voltage circuit. The test voltage source shall have a capacity to supply a current of 5 mA with a maximum voltage drop of 10 percent.

6.3 The proof voltage shall be applied between the bare conductor and the metal shots (which are earthed), for a period of 1 minute as shown in Fig. 1.

6.4 Care shall be taken in all cases to avoid mechanical damage of the test specimens. The specimens that fail the test voltage are discarded and the remaining ones are returned to the oven for the next cycle of temperature exposure.

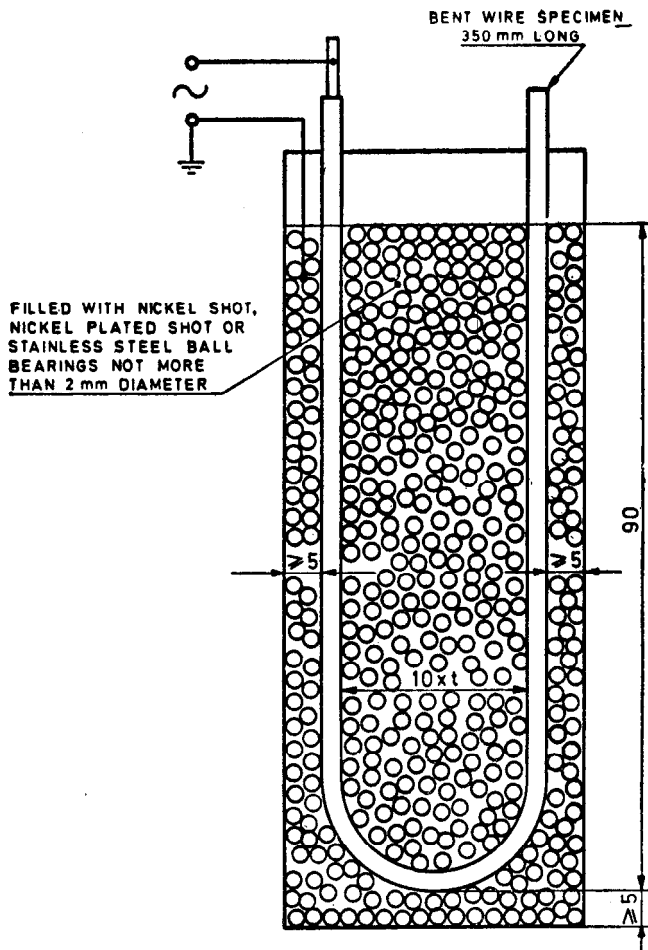


FIG. 1 ARRANGEMENT FOR BREAKDOWN VOLTAGE TEST USING SHOT BATH

7. CALCULATION

7.1 The cycles of temperature exposure, cooling and application of test voltage are continued until 11 specimens have failed at each exposure temperature.

7.2 The median life of specimens at each ageing temperature is calculated by taking the failure time of the eleventh specimen, that is, the exposure

time in hours taken to cause 11 specimen to fail minus half the duration of cycle in hours.

7.3 The same is repeated at other exposure temperatures. The test specimens are subjected to 4 exposure temperatures which lie 20°C apart at the initial two temperature ranges of three exposures and the last two highest temperatures shall be at 10°C apart. It is recommended that the lowest ageing temperature should be 20°C above the anticipated temperature index for the varnish bonded glass fibre lapped or braided rectangular copper conductors. The life-temperature characteristic is plotted on a graph paper; the failure times are plotted with a logarithmic scale on the ordinate and the reciprocal of the absolute temperature as the abscissa. The data so obtained may not permit accurate extrapolation in which case a line of best fit may be drawn statistically, and extrapolated to 20 000 hours.

In the median life procedure, if median life of less than 100 hours is obtained at the highest exposure temperature, it should be disregarded. A statistical analysis of the thermal endurance test results is given in Appendix A.

APPENDIX A

(Clause 7.3)

STATISTICAL ANALYSIS OF THE THERMAL ENDURANCE TEST RESULTS

A-1. STATISTICAL ANALYSIS OF THE THERMAL ENDURANCE TEST RESULTS

A-1.1 Method of Calculating Line of Best Fit — As the graphical fitting of a straight line to the plotted points does not always permit accurate extrapolation, the method of least squares shall be used for obtaining the line of best fit, as follows:

A-1.1.1 It is assumed that the specimens deteriorate in a manner expressed by the following equation:

$$L = Ae^{b/T} \quad \dots \quad \dots \quad \dots \quad \dots \quad (1)$$

where

- L = life of specimens,
- A, b = constants for the specimens,
- e = base of natural logarithms, and
- T = absolute temperature in K.

A-1.1.1.1 Equation (1) may be expressed as a linear function by taking logarithms:

$$\log_{10} L = \log_{10} A + \frac{b}{T} \log_{10} e \quad \dots \quad (2)$$

If $y = \log_{10} L$, $a = \log_{10} A$, $b' = b \log_{10} e$, and $X = 1/T$,
then $y = a + b' X \quad \dots \quad (3)$

Hence, if data obtained from testing at higher temperatures are plotted on graph paper and so constructed that equal increments on the axes of abscissae and of ordinates respectively represent equal increments of $1/T$ and $\log L$, they may be expected to fall on a straight line. Such a line could be used for extrapolation to lower temperatures.

A-1.1.2 It may be found in practice that the data, when so plotted, falls only approximately on a straight line. In this case a line of 'best fit' may be determined by the 'least squares' method, that is, by determining the regression Y upon X . The values of the constants of equation (3) are calculated as follows:

$$b' = \frac{\Sigma XY - (\Sigma X)(\Sigma Y)/n}{\Sigma X^2 - (\Sigma X)^2/n} \quad \dots \quad (4)$$

$$a = (\Sigma Y - b' \Sigma X)/n \quad \dots \quad (5)$$

where

ΣXY = sum of products of X and Y ,

ΣX = sum of values of X ,

ΣY = sum of values of Y ,

n = number of values of X (or of Y), and

ΣX^2 = sum of values of X^2 .

$$\text{But } T = \frac{1}{X} = b' / (\log_{10} L - a) \quad \dots \quad (6)$$

Hence T may be found for any value of L .

A-1.1.3 To simplify the handling of the test data used in the equation, it is suggested that it should be tabulated as in Table 3 and the calculation be performed as in the model set out below:

- In col 1 and 2, list the measured exposure temperatures in $^{\circ}\text{C}$ and K ;
- In col 3 and 4, list the reciprocals and the squares of reciprocals of the absolute temperatures ($X = 1/T$ and $X^2 = 1/T^2$);
- In col 5, list the corresponding lives (L) in hours;
- In col 6, list the logarithms of the values in col 5 ($Y = \log_{10} L$);

- e) In col 7, list the products of Y (from col 6) and X (from col 3);
- f) Sum col 3,4,6 and 7 and enter the respective sums at the bottom of each column;
- g) Enter the number of exposure temperature, n ;
- h) Use these sums and this number to calculate b' from equation (4);
- j) Calculate a from equation (5);
- k) Substituting these values for a and b' and 20 000 h for L in equation (6), find the corresponding value of T and hence of temperature in $^{\circ}\text{C}$;
- m) Repeat step (k) for a smaller value of L , for example, 2 000 h;
- n) Plot the ' lives ' and temperatures from (k) and (m) on $\log L$ versus $1/T$ graph paper and join them; this gives the regression line; and
- p) On the same graph, plot the points representing average or median lives and corresponding temperatures.

TABLE 3 SUGGESTED LAY OUT OF DATA AND SAMPLE CALCULATION

(Clause A-1.1.3)

TEMPERATURE $\underbrace{\text{ }^{\circ}\text{C} \quad \text{K}}$		$X = \frac{1}{T}$	$X^2 = \frac{1}{T^2}$	L	$Y = \log_{10} L$	$XY = \frac{\log L}{K}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)
180	453	$2.207\ 51 \times 10^{-3}$	$4.873\ 10 \times 10^{-6}$	—	—	—
200	473	$2.114\ 16 \times 10^{-3}$	$4.469\ 67 \times 10^{-6}$	—	—	—
210	483	$2.070\ 39 \times 10^{-3}$	$4.286\ 51 \times 10^{-6}$	—	—	—
220	493	$2.028\ 40 \times 10^{-3}$	$4.114\ 41 \times 10^{-6}$	—	—	—
$n =$		$\Sigma X =$	$\Sigma X^2 =$		$\Sigma Y =$	$\Sigma XY =$

The values to be entered in col 5, 6 and 7 will depend on the experimental data.

The values in col 1 and 2 are only for example; the values in col 3 and 4 depend on values in col 1. These values do not imply that the glass fibre covered strip is necessarily tested at these test temperatures.

A-1.1.4 The commonly used test temperatures in $^{\circ}\text{C}$ and K along with the reciprocals and reciprocal squared values are given in Table 4.

**TABLE 4 COMMONLY USED TEST TEMPERATURES IN °C AND K
WITH RECIPROCAL AND RECIPROCAL SQUARED VALUES**

(Clause A-1.1.4)

°C (1)	K (2)	$X = 1/K$ (2)	$X^2 = 1/K^2$ (4)
105	378	$2.645\ 50 \times 10^{-3}$	$6.998\ 67 \times 10^{-6}$
120	393	$2.544\ 53 \times 10^{-3}$	$6.474\ 63 \times 10^{-6}$
130	403	$2.481\ 39 \times 10^{-3}$	$6.157\ 30 \times 10^{-6}$
140	413	$2.421\ 31 \times 10^{-3}$	$5.862\ 74 \times 10^{-6}$
150	424	$2.364\ 07 \times 10^{-3}$	$5.588\ 83 \times 10^{-6}$
160	433	$2.309\ 47 \times 10^{-3}$	$5.333\ 65 \times 10^{-6}$
170	443	$2.257\ 34 \times 10^{-3}$	$5.095\ 58 \times 10^{-6}$
180	453	$2.207\ 51 \times 10^{-3}$	$4.873\ 10 \times 10^{-6}$
190	463	$2.159\ 83 \times 10^{-3}$	$4.664\ 87 \times 10^{-6}$
200	473	$2.114\ 16 \times 10^{-3}$	$4.469\ 67 \times 10^{-6}$
210	483	$2.070\ 39 \times 10^{-3}$	$4.286\ 51 \times 10^{-6}$
220	493	$2.028\ 40 \times 10^{-3}$	$4.114\ 41 \times 10^{-6}$
230	503	$1.988\ 07 \times 10^{-3}$	$3.952\ 42 \times 10^{-6}$
240	513	$1.949\ 32 \times 10^{-3}$	$3.799\ 85 \times 10^{-6}$
250	523	$1.912\ 05 \times 10^{-3}$	$3.655\ 94 \times 10^{-6}$
260	533	$1.876\ 17 \times 10^{-3}$	$3.520\ 01 \times 10^{-6}$
270	543	$1.841\ 62 \times 10^{-3}$	$3.391\ 56 \times 10^{-6}$
280	553	$1.808\ 32 \times 10^{-3}$	$3.270\ 02 \times 10^{-6}$
290	563	$1.776\ 20 \times 10^{-3}$	$3.154\ 89 \times 10^{-6}$
300	573	$1.745\ 20 \times 10^{-3}$	$3.045\ 72 \times 10^{-6}$

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WINDING WIRES

IS:

- 482-1968 Reels for covered, round electrical winding wires (*second revision*)
- 2069-1962 Drums for covered winding wires and strips for electrical purposes
- 3855 (Part I)-1978 Rectangular and square enamelled copper conductors: Part I Thickness of enamel coatings (*first revision*).
- 3855 (Part II)-1979 Rectangular and square enamelled copper conductors: Part II Methods of tests (*first revision*)
- 3855 (Part III)-1978 Rectangular and square enamelled copper conductors: Part III Wires with high mechanical properties (*first revision*)
- 4685 (Part I)-1968 Varnish bonded glass-fibre covered copper conductors: Part I Round wires
- 4685 (Part II)-1971 Varnish bonded glass-fibre covered copper conductors: Part II Rectangular conductors
- 4800 (Part I)-1968 Enamelled round winding wires: Part I Conductor data
- 4800 (Part II)-1968 Enamelled round winding wires: Part II Maximum overall diameters
- 4800 (Part III)-1968 Enamelled round winding wires: Part III Methods of tests
- 4800 (Part IV)-1968 Enamelled round winding wires: Part IV Wires with high mechanical properties
- 4800 (Part V)-1968 Enamelled round winding wires: Part V Wires for elevated temperatures
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- 4800 (Part IX)-1971 Enamelled round winding wires: Part IX Wires with temperature index 180
- 4800 (Part X)-1977 Enamelled round winding wires: Part X Heat bonding wires
- 5825-1970 Guide for evaluation of thermal endurance of enamelled wires
- 6160-1971 Rectangular conductors for electrical machines
- 6162 (Part I)-1971 Paper covered aluminium conductors: Part I Round conductors
- 6162 (Part II)-1971 Paper covered aluminium conductors: Part II Rectangular conductors
- 6181-1971 Varnish bonded glass-fibre braided rectangular copper conductors
- 7391 (Part I)-1974 Cotton covered copper conductors: Part I Round conductors
- 7391 (Part II)-1974 Cotton covered copper conductors: Part II Rectangular conductors
- 7404 (Part I)-1974 Paper covered copper conductors: Part I Round conductors
- 7404 (Part II)-1974 Paper covered copper conductors: Part II Rectangular conductors
- 7576-1974 Bunched enamelled copper conductors with silk covering
- 8572-1977 Paper-covered flexible/stranded copper conductors for transformer leads
- 8783-1978 PVC insulated winding wires for submersible motors
- 9148-1979 Tape wrapped rectangular copper wires with a temperature index of 220



TO

IS:9778-1981 GUIDE FOR EVALUATION OF THERMAL
ENDURANCE OF VARNISH BONDED GLASS FIBRE
COVERED RECTANGULAR COPPER CONDUCTORS

Alterations

[Page 9, clause A-1.1.1.1, equation(3), line 1 and 2] - Substitute 'Y' for 'y'.

(Page 10, Table 3, col 2, subheading) - Substitute 'T' for 'K'.

(Page 10, Table 3, col 7, heading) - Substitute
 $'XY = \log_{10} \frac{L}{T}'$ for $'XY = \frac{\log L}{K}'$.

(Page 11, Table 4):

a) col 2, heading - Substitute 'T' for 'K'.

b) col 3, heading - Substitute $'X = 1/T'$ for
 $'X = 1/K'$.

c) col 4, heading - Substitute $'X^2 = 1/T^2'$ for
 $'X^2 = 1/K^2'$.

(ETDC 33)